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LABORATORY TESTS OF SUBJECTIVE REACTIONS TO SONIC BOOM

by K. S. Pearsons and K. D. Kryter

Prepared under Contract No. NASr-58 *by*
BOLT BERANEK AND NEWMAN, INC.
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ABSTRACT

Subjects compared, in a special laboratory chamber, the subjective acceptability or noisiness of sonic booms (simulated) that would be heard outdoors and indoors with the sound of subsonic jet aircraft and bands of filtered white noise. The subjective acceptability of the booms was expressed in terms of equivalent perceived noise level in PNdB. (The use of this procedure does not imply that a "PNdB" value can, or should, be calculated for a sonic boom; the PNdB values used refer to the calculated peak perceived noise level of the flyover sound of a subsonic jet aircraft that is judged to be subjectively as acceptable as a given sonic boom.) When heard indoors, a sonic boom having an outdoor overpressure of 2.3 lb/ft^2 was judged to be as acceptable as the sound of a subsonic jet heard indoors and having an outdoor level of 113 PNdB; the same boom heard outdoors was judged to be less noisy by an equivalent of 17 PNdB than the sound of subsonic jet at 113 PNdB. Some factors involved in estimating community response to aircraft noise are discussed.

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INTRODUCTION

When the shock waves emanating from the bow and tail of a supersonic aircraft pass by a listener on the ground, he experiences, if outdoors, something which sounds, usually, like two heavy-duty rifle shots fired in quick succession. This sound is commonly called a "sonic boom." If the listener is inside his house, the sound will not be as sharp but will continue for a longer time, due to reverberation and structural vibration.

In order to obtain some quantitative evaluations of the subjective effect of sonic boom on people, we have conducted tests in which people judge the relative acceptability of the noise produced by jet aircraft flyovers with that of sonic boom. Also included were tests to learn more about people's adaptation to sonic booms with continued exposure.

EQUIPMENT AND PROCEDURE

Sonic boom chamber. Before any of these tests could be conducted, it was necessary to develop a room and instrumentation which would provide the high pressures, fast rise times and low-frequency response necessary to reproduce a sonic boom.

The room, constructed of 8-inch solid concrete block, shown in Fig. 1, has inside dimensions of 3.5 ft x 3.5 ft x 7.9 ft. high. The curtains shown in the figure were closed to cover the loudspeakers during the tests. The door is 4 inches thick, with adequate gasketing to provide a nearly airtight enclosure. Five 18-inch loudspeakers with center-tapped voice coils mounted in the walls and ceiling were used to produce the peak pressure associated with a sonic boom. The loudspeakers were driven by either a 75-watt McIntosh amplifier or a specially built d.c. power amplifier with push-pull output which utilized the loudspeaker center tap. The outdoor sonic boom was generated by means of a waveform generator called a "photoformer." This device generates an electrical waveform by following a silhouette placed in the photoformer. The indoor sonic boom, because of its complexity, was obtained from FM tape recordings made inside a house under the flight path of a jet aircraft flying at a supersonic speed.

<u>Subjects</u>. The 20 subjects for these tests consisted of 12 college students, 2 engineers, 2 housewives, 2 technicians, an architect and an artist. Their median age was 21, and they consisted of an equal number of males and females. Each subject's hearing was tested with a Békésy audiometer and found to be normal. A questionnaire given at the end of the tests showed that only four of the subjects were consistently bothered by aircraft flyovers at their homes, indicating that the group as a whole had little previous exposure to flyover noise. On the other hand, all but two of the subjects had at least heard sonic booms before, and therefore had some familiarity with the test stimuli.

Stimuli. Since the general public is found both inside and outside of buildings, attempts were made to simulate both conditions. The boom one would experience outdoors, hereafter referred to as the outdoor boom, is essentially an N-shaped wave ranging in duration from 75 to 300 milliseconds,[1,2] with the shorter durations being those produced by military fighter aircraft, and the longer durations produced by bombers and the forthcoming supersonic transport. Figure 2 shows the outdoor booms used in this series of tests. These waveforms measured inside the chamber have durations of 150 milliseconds and peak overpressures of 4 lb/ft^2 and 2.3 lb/ft^2.

The sonic boom as experienced inside a building, hereafter called the indoor boom, was obtained from FM tape recordings made inside a wooden frame building during supersonic aircraft flyovers. The duration of the N-wave outside this building was approximately 100 milliseconds. However, the sounds produced by the boom could be heard for upwards of one second inside the building. Actually, during the judgment tests the loudspeakers were kept on for 0.8 seconds following the initial peak of the indoor boom. This

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1. Maglieri, D. J., H. H. Hubbard and D. L. Lansing, "Ground Measurements of the Shock-Wave Noise from Airplanes in Level Flight at Mach Numbers to 1.4 and at Altitudes to 45,000 Feet," NASA TN D-48, Sept. 1959.

2. Maglieri, D. J. and H. H. Hubbard, "Ground Measurements of the Shock-Wave Noise from Supersonic Bomber Airplanes in the Altitude Range from 30,000 to 50,000 Feet," NASA TN D-880, July 1961.

limit was employed to avoid prolonged listening by the subject of any system background noise. The actual peak level measured at the time of recording was 0.8 lb/ft^2. For some of these tests this was amplified to 1 lb/ft^2 and for other tests, attenuated to .5 lb/ft^2. These would correspond to 4.5 and 2.3 lb/ft^2 if measured outside the building.

As can be seen in Fig. 3, the indoor boom waveform as measured in the chamber seemed to agree fairly well with the original recordings. However, it was decided that some sort of increase in the wall or window rattle was necessary. To achieve this, a 1/4 inch plywood panel was put in place of the 4 inch thick door to the test chamber. Attached to the panel was a 24 inch x 24 inch piece of window glass. As this figure shows, a change in the waveform results with the addition of higher frequency components. Although the waveform is not as similar to the original recording as that measured in the chamber without the 1/4 inch panel and window, the subjects reported that it sounded more realistic, like a "real-life" sonic boom.

For comparison with the above-mentioned sonic booms, three stimuli were chosen. The spectra for these stimuli are shown in Fig. 4. Two were recordings of aircraft flyovers near takeoff while the third was a 1/3 octave band of noise with a 2 second rise time (the time from a level 20 dB below peak, to start of peak level); a 2 second duration, and a 2 second decay time (the time from end of peak level to a level 20 dB below the peak). The two aircraft were a 707-120 with turbojet engines and a 707-320 with turbofan engines, equipped with hushkits.

Test description. During the testing sessions the method of adjustment was used. Each subject was asked to adjust the sound level of the comparison noise until, in his opinion, it was just as acceptable as the standard. The test instructions used are given in the Appendix.

It should be pointed out that the subject had complete control over the aircraft flyover and band of noise, in that he could start it, stop it, and adjust its level at will. Also, because of the gradual build-up in sound pressure level as the aircraft approached, he had an indication of what the maximum SPL would be. However, in the case of the boom, the subject knew only that within a 5 second period after he threw the switch, he did not know exactly when, he would hear a boom.

The tests we conducted are outlined in Table 1. Notice that for indoor booms and indoor booms with window, the standard and comparison are reversed in order to correct for the so-called time error encountered in judgment tests of this sort. Although desirable, this was not possible in the outdoor boom case because of limitations in our equipment.

RESULTS

Outdoor sonic boom. The results of the judgments concerning outdoor boom (Tests 1 and 6A) are plotted in Fig. 5. Calculated standard deviations of 2.0 to 2.4 for the indoor boom as comparison and 4.3 to 7.2 for flyovers and noise as comparison indicate the spread is over twice as great when aircraft flyovers and noise bands are used as comparisons.

Table 1. Testing Program

Test	Standard	Comparison
1	Outdoor Booms	Aircraft Flyovers and Noise Band
2	Indoor Booms	Aircraft Flyovers and Noise Band
3	Aircraft Flyovers and Noise Band	Indoor Booms
4	Indoor Booms with Window	Aircraft Flyovers and Noise Band
5	Aircraft Flyovers and Noise Band	Indoor Booms with Window
6a	Outdoor Booms	Indoor Booms
6b	1/3 Octave Band of Noise at 1000 cps	Octave Band of Noise at 1000 cps
6c	Octave Band of Noise at 1000 cps	1/3 Octave Band of Noise at 1000 cps

Indoor sonic boom. The data obtained from Tests 2 and 3 are plotted on Fig. 6. The standard deviations range from 5.8 to 7.5 when the flyovers and noise bands are comparison stimuli -- a little higher than for the previous case. When we reverse the standard and comparison, we notice that the standard deviation drops a little, ranging from 5.3 to 6.3.

Indoor sonic boom (with window). The data obtained from Tests 4 and 5 are shown in Fig. 7. Here standard deviations decrease slightly from 4.5 to 7.0 down to 4.5 to 5.7 when the boom becomes the comparison. The judgment data show that the addition of the plywood panel and window glass increase the annoyance considerably over that shown in the previous figure.

Results in Perceived Noise Level

The results of Test 2 were combined with 3, and 4 with 5 (to correct for any bias due to using either sonic booms or flyovers and noise band as standards) to achieve final equivalents for booms and flyovers and the 1/3 octave bands of noise. Perceived noise levels (PNL) in PNdB [3] were calculated for these combined results from the octave band data shown in Fig. 4. In all cases, the PNdB values for the two aircraft flyovers are quite similar, but the PNdB's for the 1/3 octave band of noise are relatively low. In order to check any effects of limiting bandwidth, we had the subjects compare a 1/3 octave band centered at 1000 cps with an octave band of noise of the same center frequency, and vice versa.

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3. Kryter, K. D. and K. S. Pearsons, "Some Effects of Spectral Content and Duration on Perceived Noise Level," J. Acoust. Soc. Am. 35, 866-883, 1963.

This was done at three levels. The overall levels of 74, 84 and 94 dB for the octave band noise were judged equally acceptable to 74, 83.5 and 93.5, respectively, for the 1/3 octave band noise. The PNdB's for the octave bands were about 3.5 PNdB greater than those for the 1/3 octave bands judged to be equally acceptable. If we assume an octave band of noise had been used instead of the 1/3 octave as a comparison sound, we would have the results given in Table 2.

Results of Heart Rate Measurements

It was assumed for our tests that people would adapt or become accustomed to the boom just as they have to truck noise, subsonic aircraft noise and other noises of the present age. To further investigate this assumption some boom experiments were conducted during which the subject's heart rate was monitored, using an electrocardiograph. This method for measuring startle was checked earlier using a blank pistol as a stimulus. Eleven subjects, 4 college students and 7 high school students, were tested. Each subject was told the experiment dealt with the relaxing effects of music. The subject was further told that EKG electrodes must be attached to his arms to measure these relaxing effects. The actual instructions are given in the Appendix. The test time was 10 minutes. At no time during the test was there any mention of sonic boom. During this time music was played. Also, however, at random intervals, approximately 10 outdoor sonic booms were presented.

A questionnaire given immediately following the test session indicated that all subjects did not suspect any other stimulus in addition to the music. However, all but two of them did feel that more "disturbances" would occur after the first.

Table 2. Average of Results of Sonic Boom Judgment Tests
Sonic Boom Stimulus Used as Standard

Comparison Stimuli	Outdoor		Indoor		Indoor (with window)	
	Standard = 4 lb/ft^2		Standard = 1 lb/ft^2		Standard = 1 lb/ft^2	
	Peak OA SPL	PNdB	Peak OA SPL	PNdB	Peak OA SPL	PNdB
707-120	88	100.5	80	92.5	93.5	106
707-320	87.5	100.5	80.5	93.5	92	105
Octave Band of Noise at 1000 cps*	92.5	99.5	86	93	99	106
1/3 Octave Band of Noise at 1000 cps	92	96.5	85.5	90	98.5	103
Range						
Octave and A/C	5	1	6	.5	7	1
1/3 Octave and A/C	4.5	4	5.5	3.5	6.5	3
	Standard = 2.3 lb/ft^2		Standard = 0.5 lb/ft^2		Standard = 0.5 lb/ft^2	
707-120	83	95.5	72	84.5	85.5	98
707-320	82.5	95.5	72.5	84.5	85	98
Octave Band of Noise at 1000 cps*	88	95	78	85	91	98
1/3 Octave Band of Noise at 1000 cps	87.5	92	77.5	82	90.5	95
Range						
Octave and A/C	5.5	.5	6	1	5.5	0
1/3 Octave and A/C	5	3.5	5.5	3.5	5	3

*Based on judgment tests of octave vs 1/3 octave bands of noise centered at 1000 cps

Samples of the subjects' heart rate were taken every 10 seconds throughout the 10 min period and immediately following each sonic boom. The results are shown in Figs. 8A, B, C and D.

Subjects 1 and 2 (Fig. 8A) served as control subjects in that the sonic booms were not presented to them at any time during the experiment. A comparison of the records for heart rate on Fig. 8A with the records for the subjects exposed to sonic booms shows that the booms had little or no consistent effect upon heart rate, with the exception, perhaps, for subjects 6, 7, 10 and 11 who showed a rather sharp increase in heart rate to the first boom in the series.

Table 3 shows a summary of the data from the EKG along with that from the questionnaire.

Table 3. Summary of Questionnaire and EKG Data

Questions	Number of Responses			
1. Did you expect any stimulus other than the music when you first started to take the test?	Yes	0	No	9
2. After the first disturbance did you expect any more?	Yes	7	No	2
3. Were you startled by the disturbance?	Yes	8	No	1
4. If so, by which ones?	1st	9	4th	3
	2nd	6	Remainder	2
	3rd	5		
5. Which of the disturbances was the most annoying?	1st	3	4th	4
	2nd	1	5th	1
	3rd	2	Last	1
6. If this disburbance occurred at your home 5-10 times during the day and night, how would you rate it using the following 2 continuous scales?*	Acceptable	3	Not Annoying	3
	Unacceptable	4	Extremely Annoying	6
	No Answer	2		

* Although the subject rated the booms on continuous scales, the results are divided into two categories.

Heart Rate (EKG) Information	Number of Subjects			
Heart rate increase for at least the first two booms	Yes	5	No	4
Heart rate increase after each of the last two booms	Yes	0	No	9

DISCUSSION

Indoor Listening

When a subsonic jet aircraft is at an altitude of about 1200 ft following takeoff, it is usually at a distance of about 2-3 miles from the takeoff runway (4-5 miles from start of takeoff) of an airport. The median of the peak perceived noise level of the sound measured indoors directly under a subsonic turbofan aircraft at 1200 ft is usually in the order of 97 dB (112 PNdB measured outdoors).[4]

At a distance of about 1 1/2 miles on either side of the path directly under the subsonic jet aircraft, the median of the peak perceived noise level drops to 85 PNdB[4] outdoors and 70 PNdB indoors.

It should be noted that because of the nature of the shock wave and the height of the supersonic aircraft when it first becomes supersonic (est. 40,000 ft) the overpressure of the boom is attenuated at a much less rapid rate as a function of the distance from the center of the path directly under the aircraft than is the sound of subsonic aircraft at an altitude of 1200 ft or so. For example, for a supersonic transport at an altitude of 40,000 ft

4. Bolt Beranek and Newman Inc. Report No. 821, "Planning Guide for Aircraft Noise in Residential Areas," under Contract No. AF 33 (657)-9530 with Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, December 1962.

the overpressure on the ground directly below would be 2 lb/ft^2.[5] At 4 miles on either side of the flight path of a supersonic aircraft, the overpressure would be 1.75 lb/ft^2 or only about 1 dB different than directly under the aircraft. Therefore, it appears that when heard indoors and with some window rattle present, in a path 8 miles wide under the flight path, the sonic boom anticipated from future commercial supersonic aircraft at an altitude of about 40,000 ft would be, on the average, subjectively, about equally noisy as the sound now heard indoors in a space about 1/2 mile wide under the flight path of transcontinental subsonic turbofan aircraft at an altitude of about 1200 ft.

Outdoor Listening

For outdoor listening it appears that a sonic boom having a peak overpressure of 2.3 lb/ft^2 will be considerably more acceptable than the sound, also heard outdoors, directly under a subsonic jet aircraft at an altitude of 1200 ft -- 112 PNdB for the subsonic jet vs an equivalent 96 PNdB for the outdoor boom. However, at points one mile to either side of the flight paths, the two sounds would, apparently, be judged about equal, and at further distances to the sides of the flight path, the sonic boom would presumably be judged as less acceptable than the sound of subsonic jet at an altitude of about 1200 ft.

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5. Supersonic Transport Propulsion Requirement. IAS Preprint in Aerospace Engineering, Sept. 1961.

Factors Contributing to Different Acceptability of Sounds Tested

This difference in the greater acceptability of the sonic boom heard outdoors than the same boom heard indoors with windows, can probably be jointly attributed to the shorter duration of the outdoor boom (approximately 0.2 sec vs approximately 0.8 sec) as well as differences in the spectra of the boom in the two different environments. One would expect, on the basis of previous studies of the effects of duration and spectrum on judged noisiness,[3] that the outdoor boom would be noisier than the indoor boom because higher frequency components were relatively more intense in the outdoor boom than in the boom after it had passed through the house structure, which would attenuate the higher frequency components more than the lower. On the other hand, we would expect that the outdoor boom would be less noisy than the indoor boom because it was of short duration. To some extent, then, these two factors counteract each other for these particular exposure conditions.

In that connection it is interesting to note that although the indoor (no window) boom was not appreciably longer than the indoor-with-window boom, the boom with no window was judged to be relatively much more acceptable than the boom with window by a factor equivalent to about 13 dB. This latter difference is, no doubt, related to some additional unpleasantness in the sound associated with the "rattle" of glass or other structures. In any event, the adding of wooden door and window appreciably increased the relative noisiness of the indoor boom. We do not know whether this is due merely to addition of frequency components to the boom or to some more subtle psychological factor.

Startle effects. The results shown in Fig. 8 on the startle due to the sonic booms seem to indicate two categories of people -- those who did not appear to be startled at all throughout the test and those who were startled initially but adapted to the startle after the first boom or so. The questionnaire responses showed only one subject who admitted he was not startled by the booms although four subjects had no increase in their heart beat. Other responses indicate more people were startled by the first few booms than the last. This agrees with the EKG data which showed less startle toward the end of the sessions. There seems to be no trend in the subject's judgment of which boom was most annoying, although more than half of the subjects indicated these booms were unacceptable and annoying if they occurred 5 to 10 times during the day and night. Although laboratory experiments are open to question with respect to their validity for "real-life" situations, our findings indicate that persons would quickly adapt to the sound of sonic booms of the levels investigated once they have experienced several booms. This adaptation to intense sounds has also been found by other investigators.[6,7]

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6. Davis, R. C., "Electrical Skin Resistance Before, During, and After a Period of Noise Stimulation," J. Exp. Psycho. 15, 108-117, 1932.

7. Finkle, A. L. and J. R. Poppen, "Clinical Effects of Noise and Mechanical Vibrations of a Turbo-Jet Engine on Man," J. Appl. Physiol. 1, 183-204, 1958.

Comparison of Results with Other Studies

Broadbent and Robinson[8] recently reported the results of a study somewhat similar to ours. Those investigators found that a sonic boom recorded indoors and having an outdoor peak overpressure of 1.9 lb/ft^2 would be judged to be equally annoying as the sound of a subsonic jet or piston aircraft at 95 PNdB.

Our Table 2 shows that an outdoor peak overpressure of 2.3 lb/ft^2 was equivalent, for indoors (with window) listening to the sound of a subsonic jet at 98 PNdB. Adjusting the peak overpressures in the two studies to be equal would result in equal PNdB values.

This similarity in the results for indoor listening of these two studies is most gratifying. Broadbent and Robinson did not, however, investigate the subjective effect of outdoor booms.

Broadbent and Robinson, using a total of 79 subjects, found no significant differences among the results of male and female subjects or persons connected with flying and persons not connected, by occupation, with flying. They found that older persons showed slightly more annoyance to the sound of a jet than that of a piston aircraft; otherwise, different age groups responded about the same to the different noises. Although we did not have a sufficient number of subjects to examine possible differences in results for different occupations, age groups, etc., we found no significant differences as a function of sex; nor were there any apparent trends in the results for the college students vs housewives engineers, etc.

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8. Broadbent, D. E. and D. W. Robinson, "Subjective Measurements of the Relative Annoyance of Simulated Sonic Bangs and Aircraft Noise," J. Sound and Vibration I (2), 162-174, 1964.

Finally, Robinson and Broadbent report that when the sound pressure level of the boom was increased by, say, 6 dB, the sound pressure level of the sound of a subsonic aircraft, judged to be equally noisy to the boom at the lower level, had to be increased by about 7.5 dB to be judged equal to the sonic boom. We found a very similar relationship for the indoor boom (a 6 dB increase in the boom required a corresponding increase of 8 dB in the sound of the subsonic aircraft in order that they be judged equally acceptable). However, for the outdoor listening the subjective noisiness of the two types of sounds increased equally with equal changes in sound pressure level -- a 5 dB change in peak overpressure (2.3 lb/ft^2 to 4 lb/ft^2) required a 5 dB change in peak sound pressure level of the subsonic jet (83 to 88 dB) -- in order that the sounds be judged comparable.

We concur with Broadbent and Robinson that although the subjective noisiness, or "annoyance" of the sonic boom may change somewhat more rapidly with a change in sound pressure level than it does for other more conventional sounds, the scale used for growth of perceived noise level as a function of sound pressure level is appropriate for equating sonic booms with other sounds, at least for the range of levels used in their and our studies.

Estimating Community Response to Sonic Boom

It is possible to make only tentative estimates, on the basis of reactions to sounds presented in a laboratory, as to how people will respond to similar sounds in real life. However, we believe some estimations along these lines can be made with regard to the sounds from aircraft, because: (1) there is considerable knowledge about the behavior of people and communities subjected to the noise of present-day aircraft, and (2) the information obtained in the laboratory studies is based on judgments of the <u>relative</u> noisiness or acceptability of different types of sounds. It is perhaps not unreasonable to expect at least to a first order of approximation that the <u>relative</u> differences in the subjective noisiness among sounds studied in the laboratory would also be found under real-life conditions, provided other environmental factors were more or less constant.

It has been previously shown[9] that the response of people to aircraft noise is a function not only of the peak PNdB level of the sound of individual aircraft flyovers, but is also controlled by the number of exposures per day and the time of their occurrence. It would seem, therefore, that:

a) the acceptability of the sonic boom might be favorably influenced by there being, if indeed this will be the case, but a few flyovers per day for any one community; but

b) the sonic boom may result in more complaints, in that a large population of people would be exposed to a noise as subjectively intense as that now being experienced by but a few people near airports. For example, it seems likely that the people in a path 8 miles or so wide, under a supersonic jet at a 40,000 ft altitude, would hear, when indoors, a boom and related house-response sounds that are subjectively equivalent to the sound now heard by people indoors in a path, say, 1/3 mile wide, directly under a subsonic jet aircraft, when the aircraft is at an altitude of about 1200 ft following takeoff.

As aforementioned, the above deductions are based on extrapolations and interpretations of research data and opinions that represent statistical trends and averages; as such, they will not necessarily be valid for any one particular situation or community exposed to sonic booms and other types of sounds from aircraft.

CONCLUSIONS

The following comments are made with the considerations mentioned in the preceding paragraph in mind. It is suggested that:

1. A sonic boom of 2.3 lb/ft^2 measured outdoors may, in real life, be found generally objectionable when heard indoors inasmuch as:

   a) the laboratory tests showed that a 2.3 lb/ft^2 boom, measured outdoors but heard indoors, would be equivalent in acceptability to the sound heard indoors of a subsonic aircraft flyover measuring about 113 PNdB outdoors or about 98 PNdB if measured indoors; and

   b) the sounds of present-day conventional aircraft at 110-112 PNdB outdoors (measuring 97 PNdB indoors) are generally thought to be near the upper limit of tolerable noise levels and are the levels now experienced by people who are situated no more than 2-3 miles from the runway (4-5 miles from start of takeoff) of a commercial airport and directly, or nearly so, under the flight path of the aircraft.

2. A sonic boom of 2.3 lb/ft^2 measured outdoors will probably not be generally objectionable in real life when heard outdoors inasmuch as:

   a) in the laboratory tests, the subjects judge a sonic boom having a peak overpressure of 2.3 lb/ft^2 to be equivalent to the sound of a subsonic aircraft at 95.5 PNdB:

b) 95.5 PNdB heard outdoors is thought to be tolerable inasmuch as this is considerably less than the 112 PNdB now experienced by some people near airports. (The majority of complaints about aircraft noise are with regard to interference with activities in the home, speech, listening, sleep, etc.)

3. Startle reactions to sonic booms will probably not be a significant factor as a cause of annoyance with repeated regular exposures to sonic booms having outdoor peak overpressures of at least 2.3 lb/ft^2 inasmuch as this study, as have others, shows that man adapts both physiologically and psychologically with repeated exposure to sounds of this intensity.

APPENDIX

Instructions Used in Sonic Boom Judgment Tests

INSTRUCTIONS - Judgments of Aircraft Noise

The purpose of these tests is to determine the relative acceptability of noises from different types of aircraft. The tests are part of a program of research designed to obtain information that will be of aid in the design of military and civilian airports and future supersonic aircraft.

When you throw the switch on the control box to No. 1, you will experience a "sonic boom" similar to that produced by an aircraft flying faster than the speed of sound. By throwing the switch to position No. 2 you will hear the noise made by an aircraft passing overhead or an artificial noise. We will call the "sonic boom" from switch position No. 1 the "standard" and the noise from switch position No. 2 the "comparison." The duration of the comparison noise (No. 2) is always much longer than the standard noise (No. 1). You cannot change the duration of either stimulus but you can change the overall intensity of the comparison noise by turning the knob on the attenuator that is on the control box.

Your job is to listen first to the standard at position No. 1, then to listen to the comparison noise at position No. 2, and then to adjust the intensity of the comparison noise until it sounds as acceptable to you as the standard. By equally acceptable we mean that you would just as soon have one as the other out of doors at home periodically 20 to 30 times during the day and night. Stated another way, we mean by equally acceptable that the comparison noise would be no more nor no less disturbing to you when heard out of doors at your home than the standard.

You may turn back and forth between the two stimuli as often as you wish and listen to each as long as you wish. It is suggested that before you proceed to equate the comparison to the standard you make the comparison noise (No. 2) much more intense than the standard (No. 1); then make the comparison noise much less intense than the standard. With those limits established, adjust the intensity of the comparison noise until it would be just as acceptable as the standard outside your home as the result of an airplane flying overhead.

Please switch from the standard to comparison and vice versa during the brief pause that exists between the end and the beginning of each flyover noise.

Instructions Used in Sonic Boom Adaptation Tests

INSTRUCTIONS - Effects of Music

The following experiment is designed to obtain information on the relaxing effects of music. To measure these effects two electrodes will be attached to your arms. Your only task is to RELAX and listen to the music. Please avoid any movements such as "keeping time" or shifting around in the chair.

FIG. 1 SONIC BOOM TEST CHAMBER WITH CURTAINS DRAWN TO SHOW LOW FREQUENCY SPEAKERS

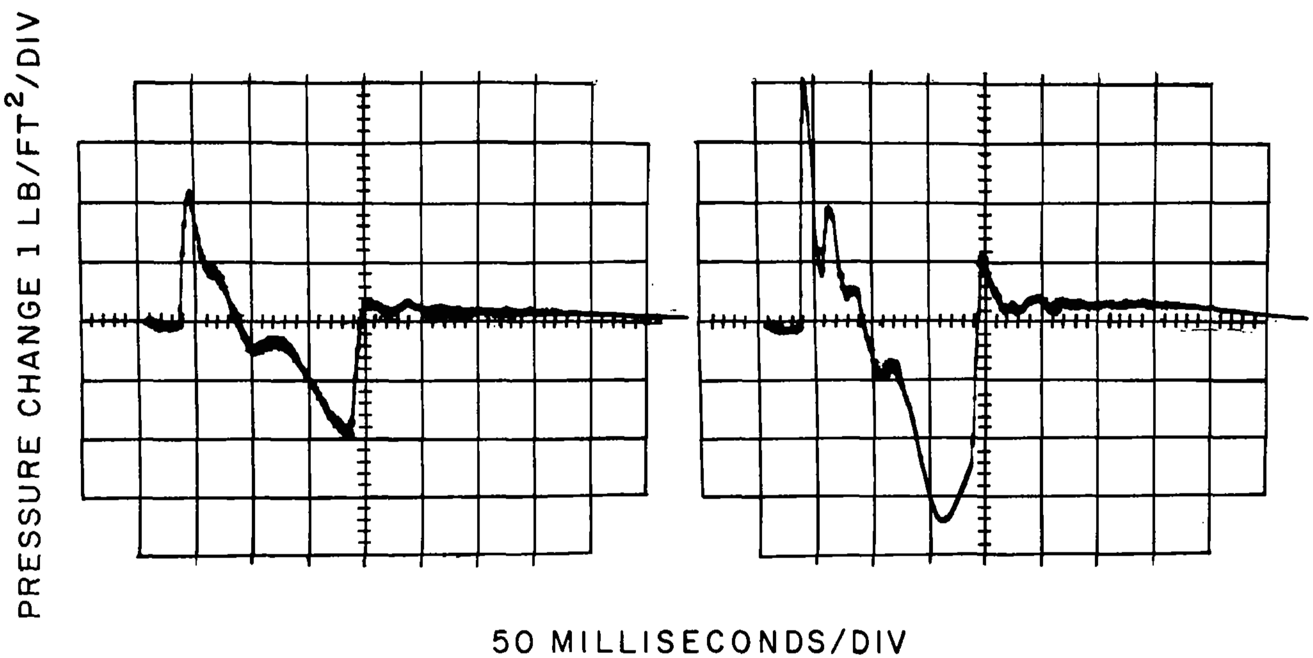

FIG. 2 WAVEFORMS OF OUTDOOR SONIC BOOM STIMULI

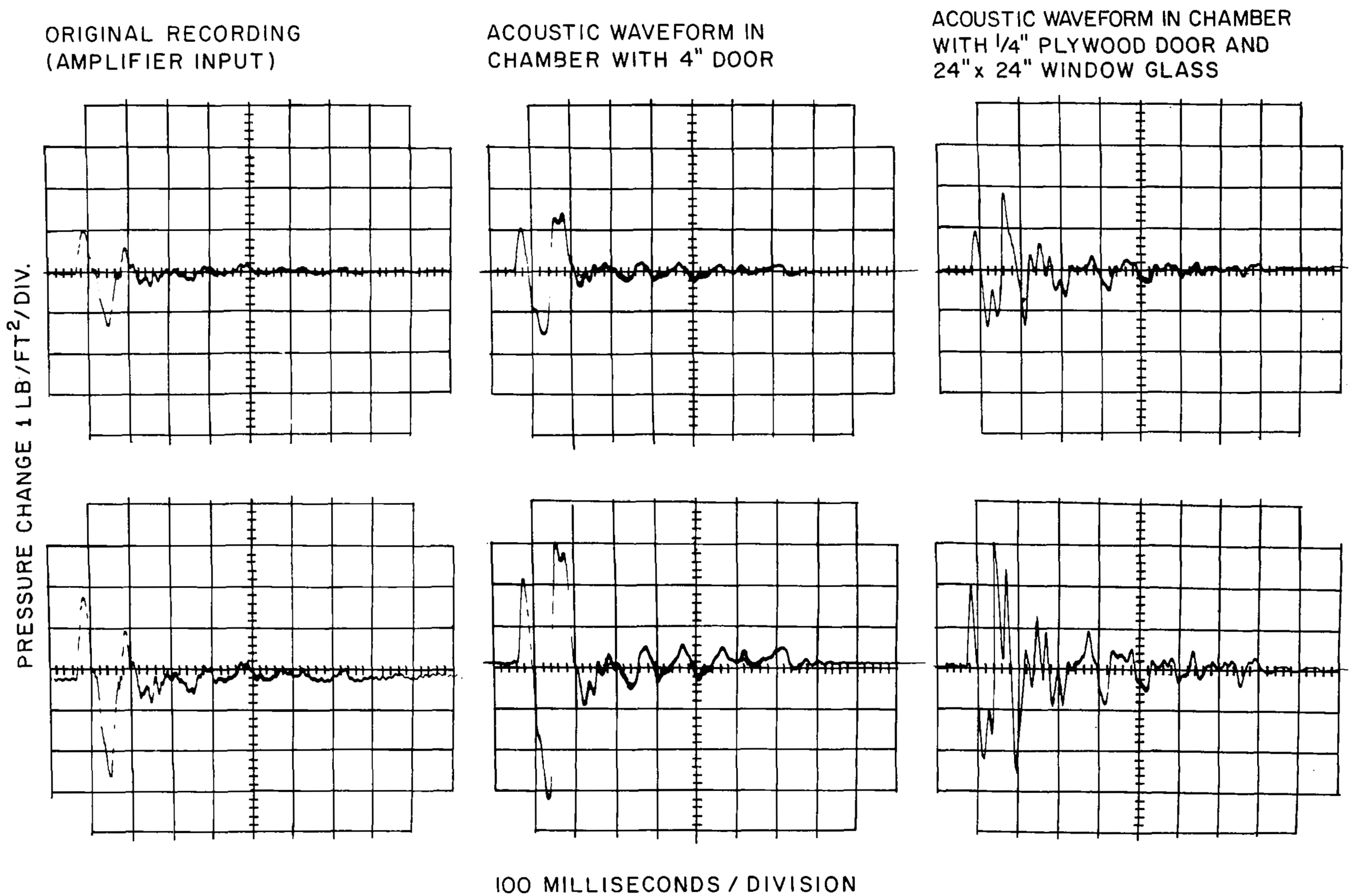

FIG. 3 WAVEFORMS OF INDOOR SONIC BOOM STIMULI

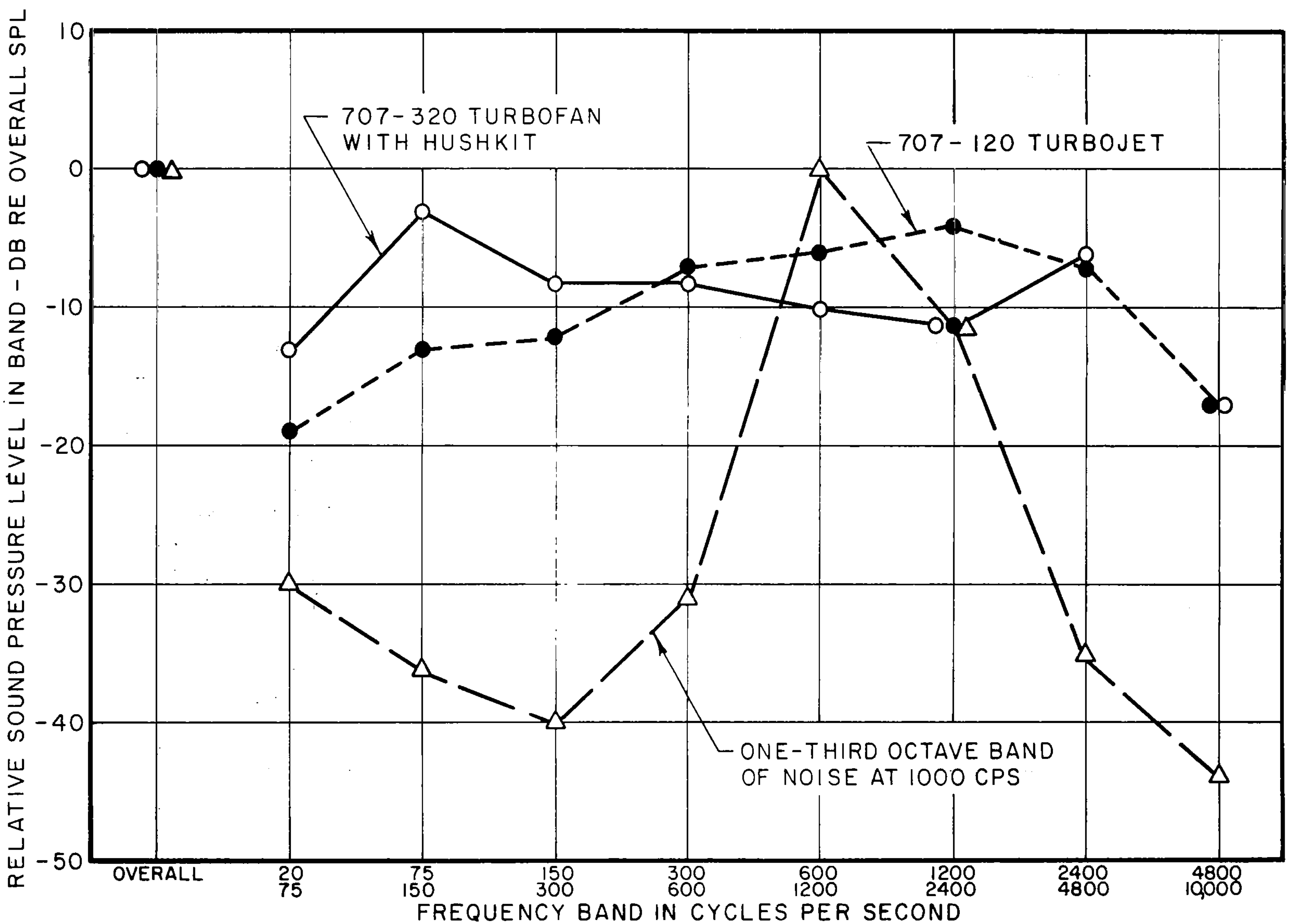

FIG. 4 SPECTRUM OF NOISE USED IN SONIC BOOM JUDGEMENT TESTS

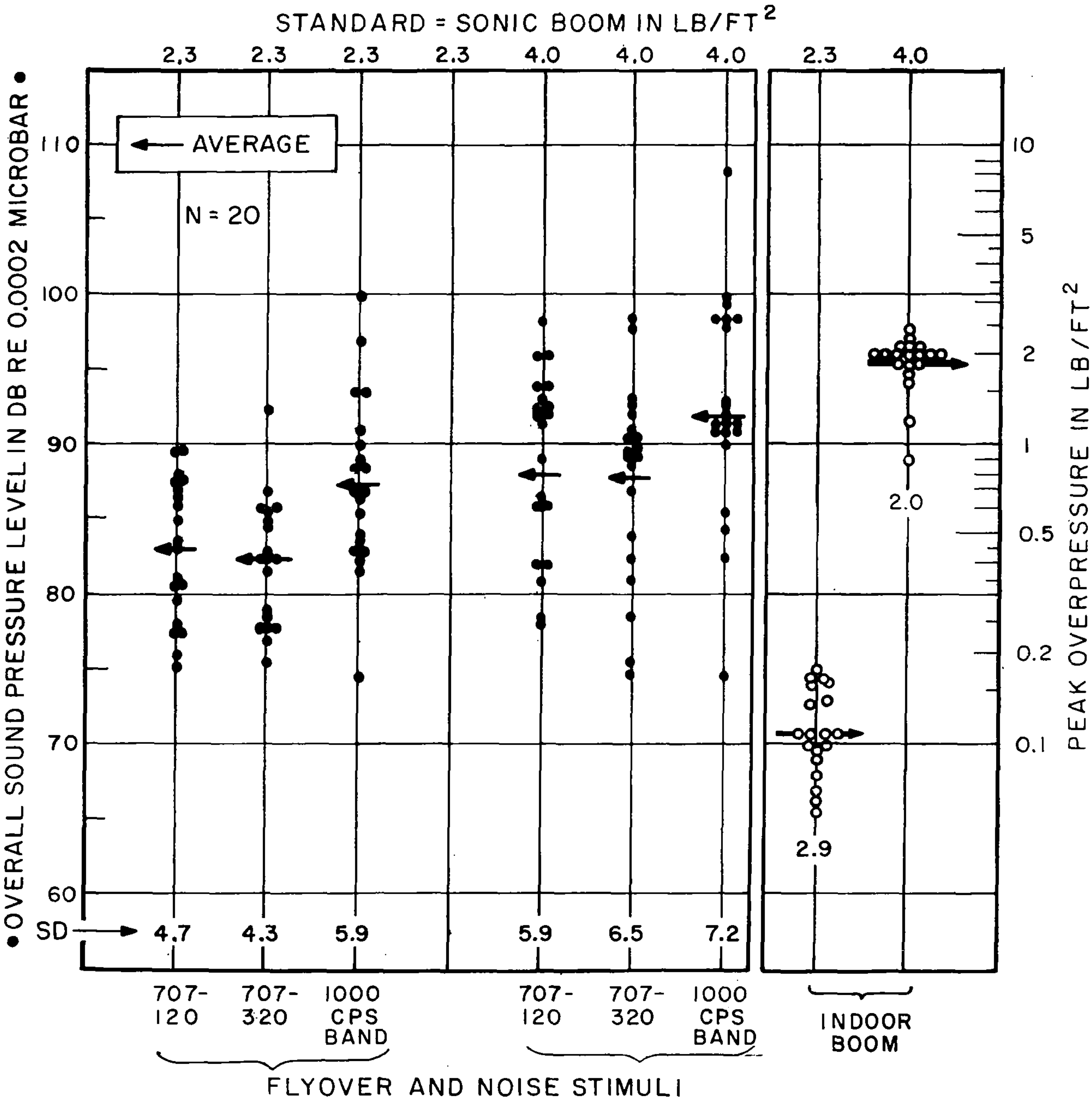

FIGURE 5.- RESULTS OF SONIC BOOM JUDGEMENT TESTS WITH OUTDOOR BOOM STIMULUS.

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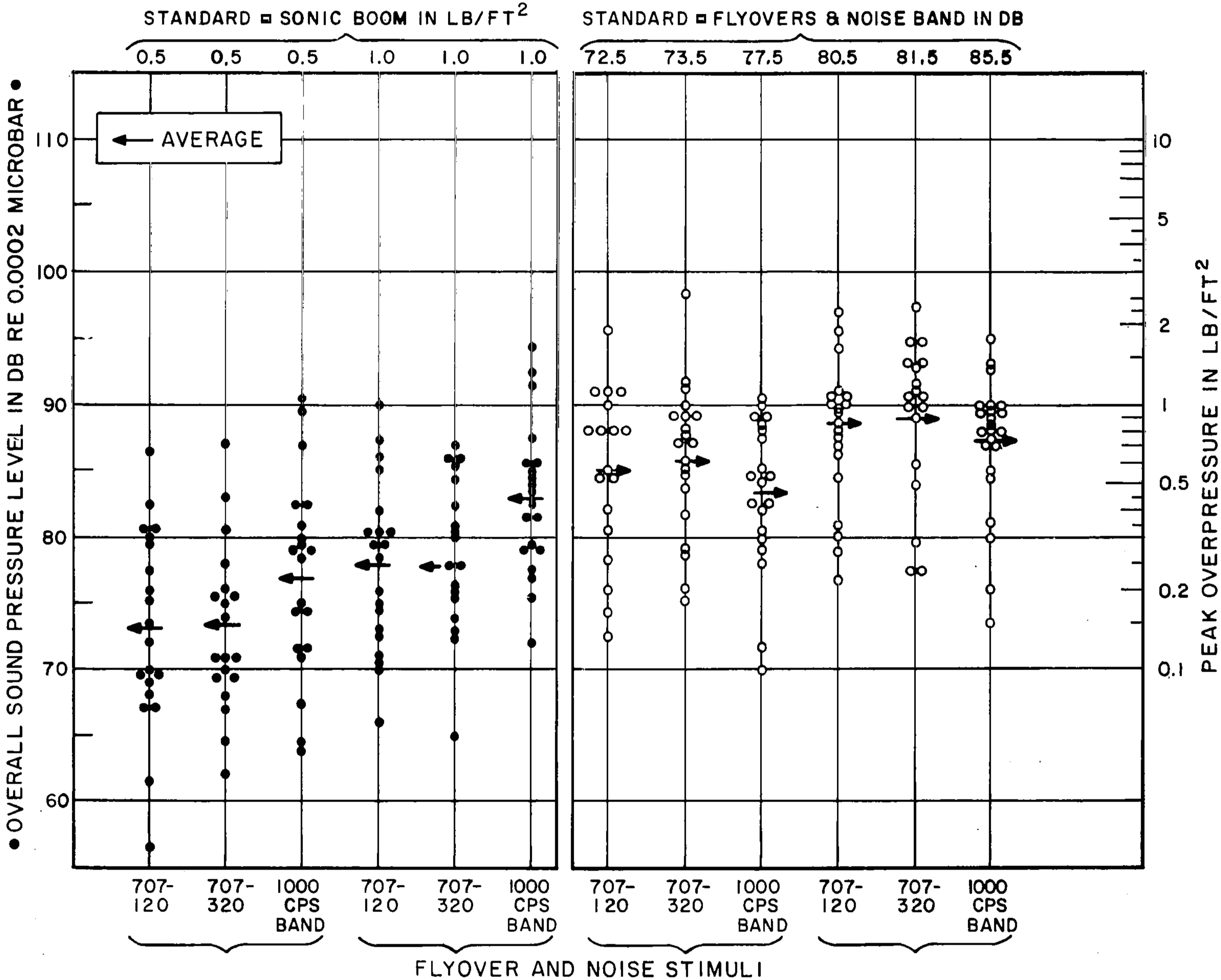

FIG. 6 RESULTS OF SONIC BOOM JUDGEMENT TESTS WITH INDOOR BOOM STIMULI

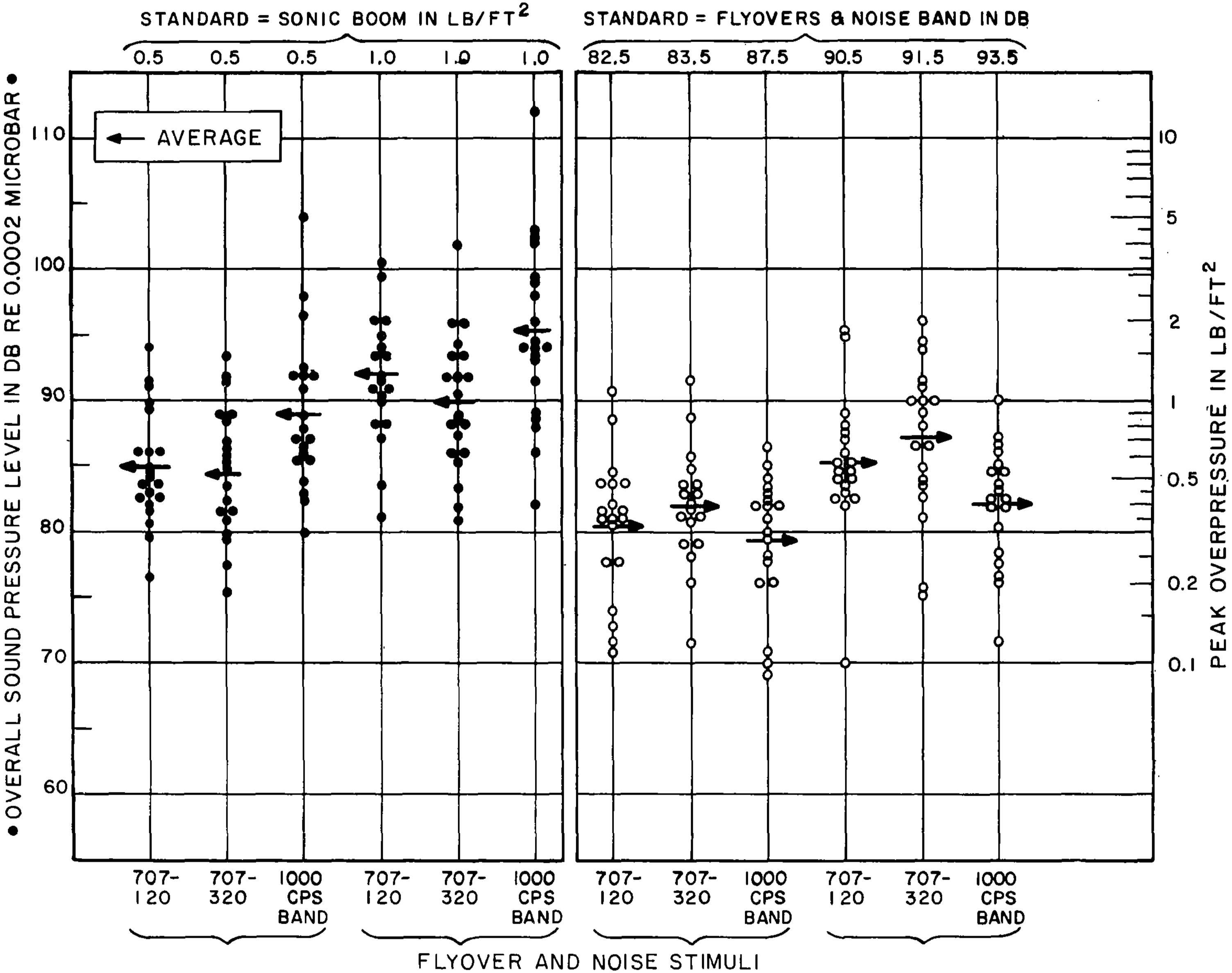

FIG. 7 RESULTS OF SONIC BOOM JUDGEMENT TESTS WITH INDOOR BOOM (WITH WINDOW) STIMULUS

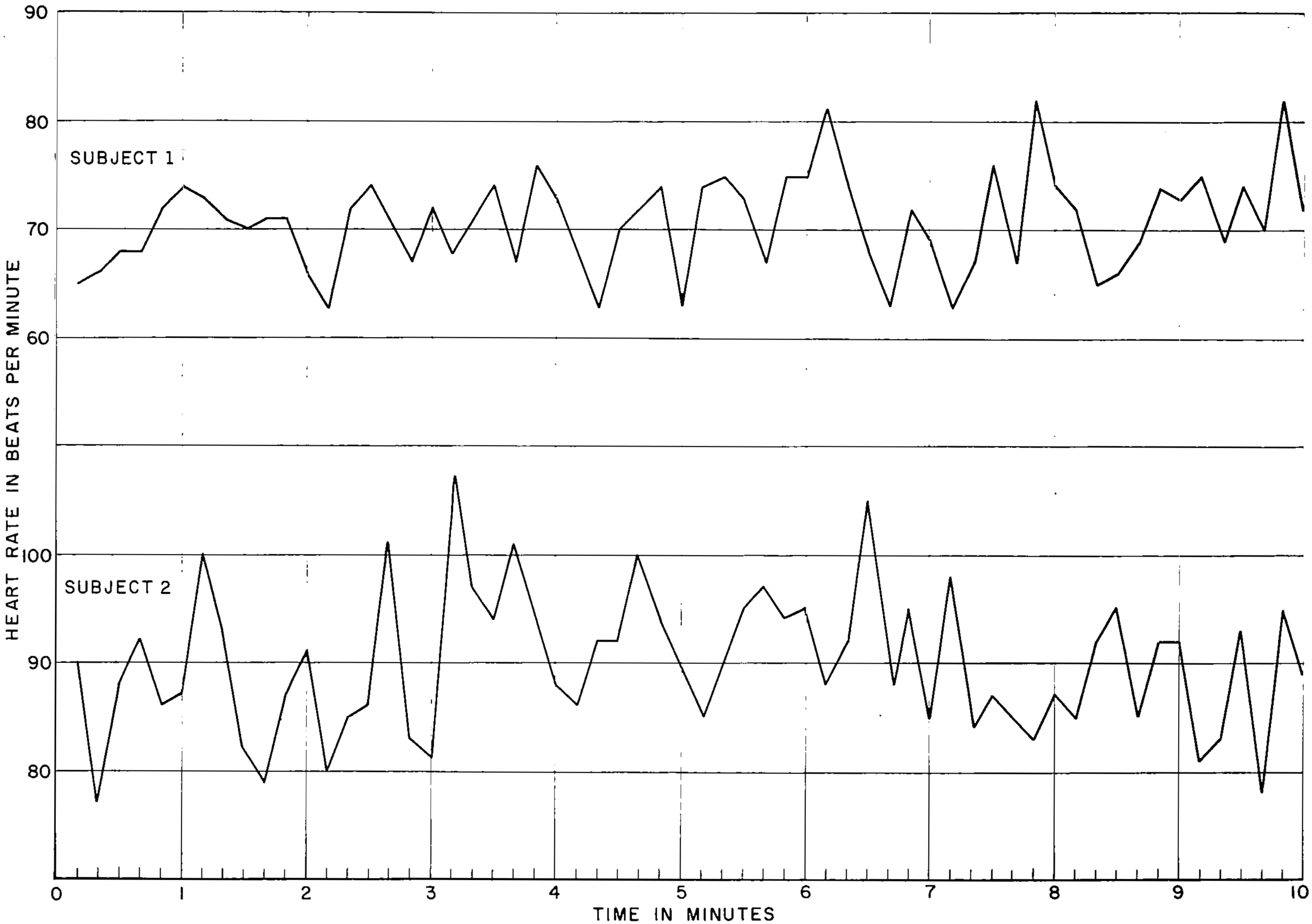

FIGURE 8A SUMMARY OF HEART RATE RECORDS
DURING SONIC BOOM EXPERIMENT FOR "CONTROL" GROUP

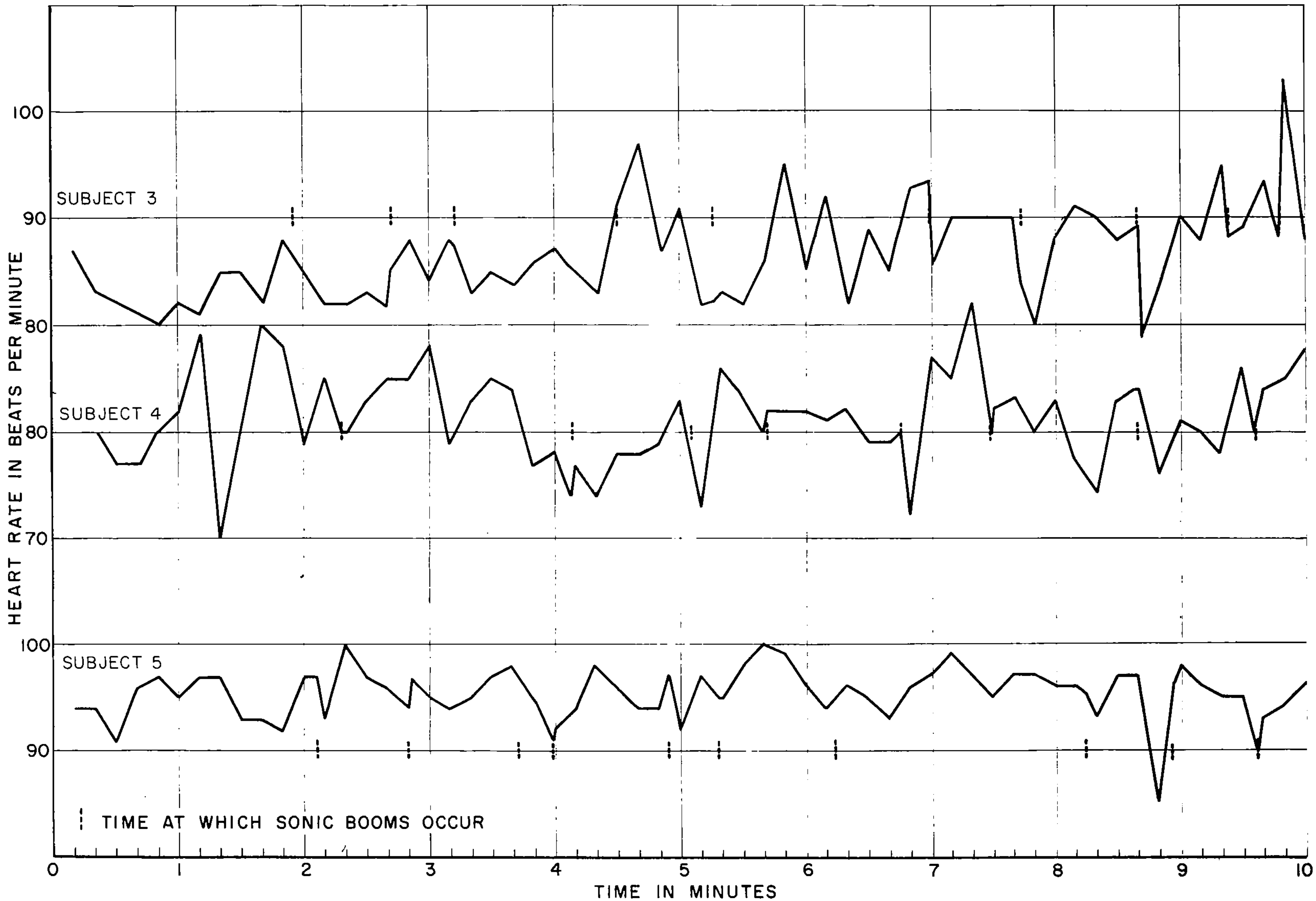

FIGURE 8B SUMMARY OF HEART RATE RECORDS DURING SONIC BOOM EXPERIMENT

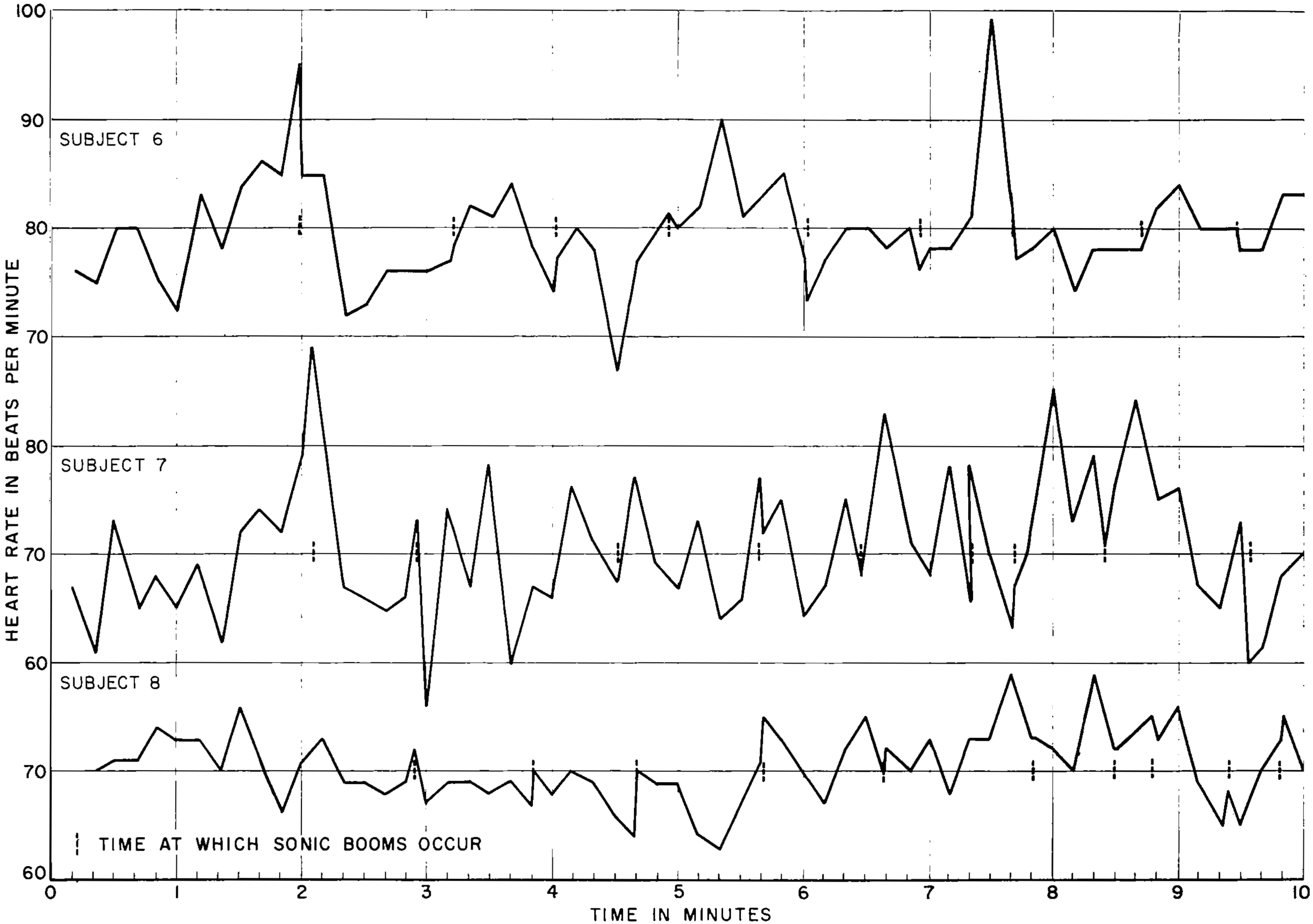

FIGURE 8C SUMMARY OF HEART RATE RECORDS DURING SONIC BOOM EXPERIMENT

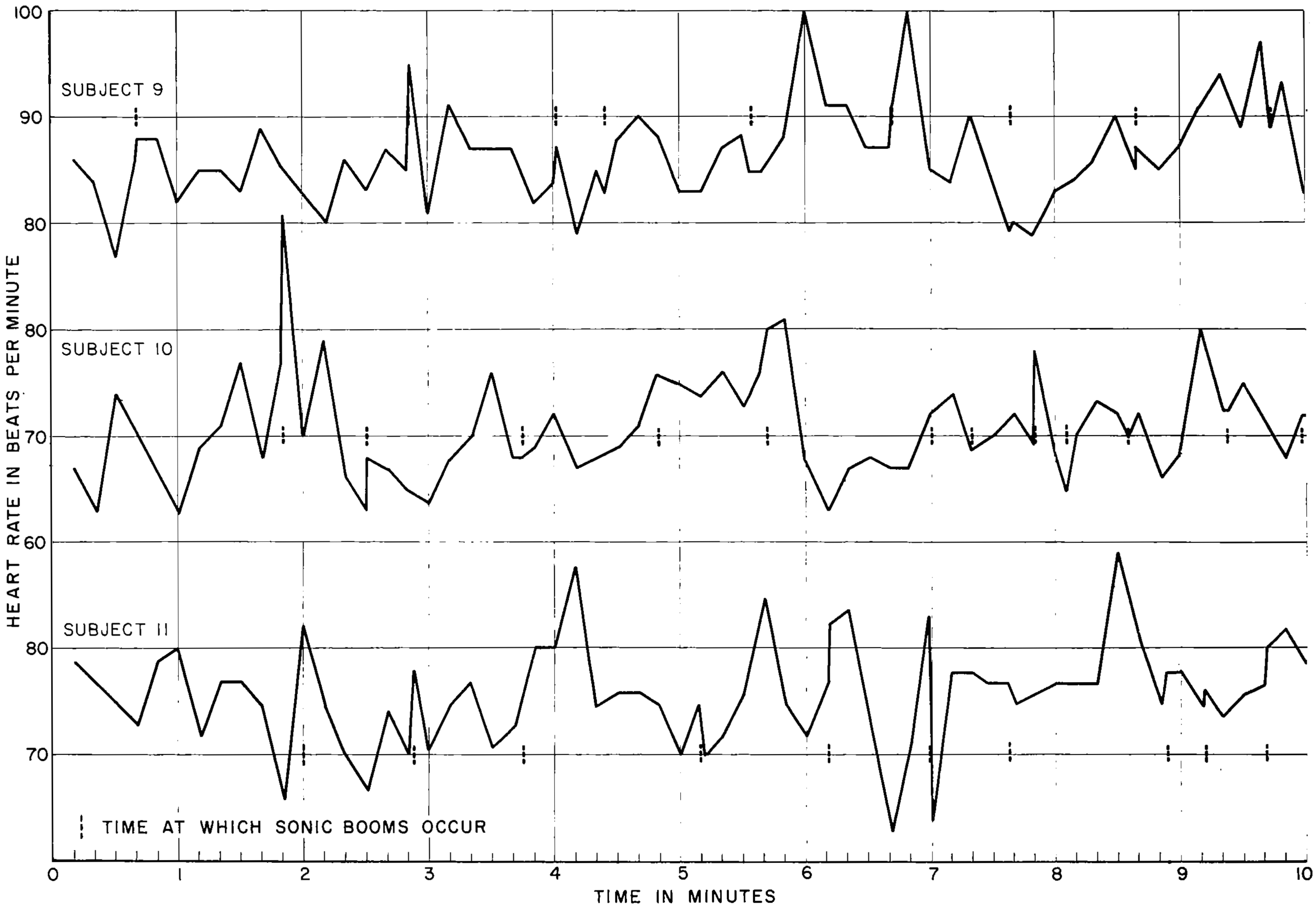

FIGURE 8D SUMMARY OF HEART RATE RECORDS DURING SONIC BOOM EXPERIMENT